SCIENTIFIC STUDY OF FLORAL DIVERSITY IN MINING REGIONS OF KEONJHAR DISTRICT, ODISHA

A thesis submitted in partial fulfilment of the requirements for the degree of

Master of Technology

In

Biotechnology

By

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CERTIFICATE

This is to certify that the research project report entitled "**Scientific Study of Floral Diversity in Mining Regions of Keonjhar District, Odisha**." submitted by **Miss Suktika Chandra** in partial fulfilment of the requirements for the award of the degree of Master of Technology in Biotechnology and Medical Engineering with specialization in Biotechnology at the National Institute of Technology, Rourkela is an authentic work carried out by her under my supervision and guidance.

To the best of my knowledge, the matter embodied in the report has not been submitted to any other University/Institute for the award of any Degree or Diploma.

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DECLARATION

The present study entitled “**Scientific Study of Floral Diversity in Mining Regions of Keonjhar District, Odisha.**” is based on my original research work and no part of the thesis has so far been submitted for the award of degree in Master of Technology in Biotechnology or any other degree or diploma to the NIT Rourkela, Orissa, India or elsewhere.

Place: Rourkela, Odisha

Date : **(SUKTIKA CHANRDA)**

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LIST OF CONTENTS

Chapter no.	Description		Page No.
	Abstract		1
1.	Introduction		2
2.	Literature review		6
3.	Materials and Methods		14
	3.1	Study Area	15
	3.2	Sample Collection and Identification	16
	3.3	Species Diversity Calculation	17
	3.4	Questionnaire Survey	20
	3.5	Mitigation Measures	20
4.	Results and Discussion		21
	4.1	Sampling Area	22
	4.2	Study Area Location Co-ordinates	22
	4.3	List of Plants	26
	4.4	Floral Diversity Chart	41
	4.5	Species Diversity Calculation	42
	4.6	Key Findings	43
	4.7	Mitigation Measures	45
	4.8	Discussion	47
5.	Conclusion		49
	References		51

LIST OF FIGURES

Sl. No.	Name of Figures	Page No.
1.	Iron ore projects in Odisha	15
2.	Map of the Study Area	16
3.	Keonjhar district of Odisha, India	22
4.	GPS points of the quadrants in the study area	23
5. (a),(b)	Collection of Quadrat data with the help of ropes and poles	23-24
6.	Identification of flora by the taxonomist	27
7.	Questionnaire survey	27
8.	Pie chart representing the percentage cover of plants from different life forms	41
9.	Some of the plants observed and identified	42

LIST OF TABLES

Sl. No.	Tables	Page No.
1.	Location Co-ordinates of Study Area	22
2.	Documentation of data in the Quadrats	24
3.	List of Plant Species identified and their ethnobotanical uses	28
4.	Enumeration of Dominant Flora and Relative density of the species	41
5.	Diversity Indices	43

Abstract

The environment comprises of animal kingdom as well as the plant kingdom. Components of both of these kingdoms are interdependent on each other, directly or indirectly. Also, each kingdom comprises of a variety of individuals in them. These lead to the biodiversity that sustains the ecosystem and thus maintains the ecological balance. This study is carried out to understand the floral diversity of the proposed mining region of Sarkunda Reserve Forest of Keonjhar district in Odisha, India. Data obtained from a year-long on-site survey led us to gathering an idea about the different species of plants found there. From the enumerated and documented data, the species diversity indices and species richness have been calculated. Also, study of the relationship between human beings and plants, termed as "Ethnobotanical studies" has been carried out in order to properly understand the significance of the floral diversity on the environment. With the advent of human civilization, mining has become indispensible. But mining activities come with their share of effects on the environment. Study of floral diversity of the proposed region was also required in order to find out suitable mitigation measures to curb the loss in biodiversity incurred due to the mining activities.

Keywords: *Biodiversity, Ethnobotanical studies, Mining, Species richness, Diversity indices*

Chapter 1

Introduction

Biodiversity is defined as the variation of biotic organisms present in terrestrial, marine and other aquatic ecosystems and all the habitats of which they are part. This includes diversity within species, between species and that of ecosystems [1]. Diversity in the biotic community is highly essential for the maintenance of balance in the environment. In a very fundamental basis this can be explained as the fact that the living organisms take up oxygen for their bodily activities and release carbon dioxide into the environment. The plants, on the other hand, take up this carbon dioxide and that leads to the photosynthesis activity which is responsible for the sustenance of the plants [2]. Also the living organisms depend on the plants for their sources of nutrition and medicine. Therefore, maintaining a proper balanced biodiversity is highly essential for sustenance of every living organism [3].

Currently, biodiversity is highly affected by mining activities all over the world. The practice of mining is highly essential for modernisation and industrialisation. The process of mining is a long drawn and a complex process [4]. Different stages of mining lead to different types of impact on the environment. The onset of the mining process leads to deforestation and loss of surface vegetation in a huge scale. The loss in vegetation hampers the balance in ecosystem [5]. After the completion of mining, the residues lead to pollution of the environment in a large scale and for a long period of time, the area remains unproductive. The idea is to find out how mining can lead to such environmental problems and then taking proper steps from the very beginning of the mining activities so as to minimise the environmental hazards and be ready for any such long term problems. In order to do that we need to evaluate the types of vegetation the area supports and the climatic conditions that the area faces [6]. In other words, finding out the floral diversity can lead to a better idea of the floral cover of the place. Here, we address the situation by conducting field trips to the mining regions of Sarkunda Reserve Forest, Odisha, throughout the year in different seasons and make a comprehensive idea about the floral diversity with the help of different diversity indices viz. the Simpson’s Diversity Index, the Shannon-Weiner Diversity Index and Simpson’s Measure of Evenness.

In the process of finding out the floral diversity of the area, a comprehensive study of the plants growing in that area should be gathered. In order to do this, questionnaire survey and interaction with the local tribal people were the main steps that were used [7]. The knowledge about the plants leads to the documentation of the ethnobotanical uses of the plants. Ethnobotany is defined as the relationship between plants and human beings; “ethno”- study of people and “botany”- study of plants. Ethnobotany, a part of Ethnobiology, deals with the study of the complex relationship between uses of the plants and cultural practices of the people [8].

The investigation of the types of plants found in the forest area leads to the discovery of plants with high medicinal, economical and nutritional values. Also, the forest houses some of the plants which are recorded as the RET listed plants [9]. RET stands for Rare, Endangered and Threatened plant species that should be taken care of in order to maintain their ecological balance in the environment and any activities that would harm them or render them in a position risking their availability in the environment should be scrapped. Hence, it was necessary to find out the status of all the plants found in that area, in order to evaluate the amount of biodiversity loss the mining activities will bestow on the ecosystem. Also, the comprehensive knowledge about the vegetation status and the weather characteristics help in finding out the mitigation measures that can be employed in the mining affected area in order to minimise the harm done in the area.

Objectives of the present study

The current study has been aimed to look into the following objectives:

1. Scientific study of floral diversity of the mining area of Sarkunda Reserve Forest, Odisha

2. Ethnobotanical data of the plants identified in the area.

3. Finding out the mitigation measures that should be employed in order to save the biodiversity loss due to mining activities.

Chapter 2

Review of Literature

The world houses innumerable species of plants and animals. Their lives are voluntarily or involuntarily interrelated in every aspect. The way these living organisms depend on each other makes the ecosystem. The various species of living organisms in an ecosystem lead to the diversity which is highly necessary for individual sustenance. This diversity of biotic components of nature is known as Biodiversity. Biodiversity deals with the diversity in the species of animals, known as the Faunal Diversity and that of the different species of plants, known as the Floral Diversity.

2.1. Significance of Biodiversity

Ecologists try to establish a possible connection between species diversity and intensity of various ecosystem processes in order to show the importance of biodiversity. But it is difficult to establish a simple connection and it involves a lot of discrepancies. The different meanings of ecosystem functioning are important for showing the importance of biodiversity. "Ecosystem functioning" is defined as the synthesis of all compounds that plants, animals and other organisms of a given community contain in their bodies or release in the environment. By this definition, biodiversity obviously cannot be diminished without some loss of ecosystem functioning. It is emphasized that attempts to conserve biodiversity do not need special justification in possible relationships between diversity and ecosystem services [10].

Assessing the biodiversity is essential for understanding the humongous species diversity. The global climate change, habitat transformation of species and the threat of extinction of the numerous species have led to the need for studying biodiversity of the world environment. The main method of studying the biodiversity of organisms is extrapolation and prediction as number by number counting of individual species is next to impossible in the real world. In case of terrestrial biodiversity, a relatively accurate idea of species can be obtained with the help of taxonomic knowledge about the different species from several independent sources.

Tropical forests are hugely under threats, mostly linked to human disturbance. Togo, a country in Africa faces the problem of continuous deforestation. It is necessary to assess woody species diversity that poses the main pillar for maintaining the forest structure and functions. A study carried out in Abdoulaye Wildlife Reserve (AWR) for the same objective, brought out a result that showed that total of 258 plant species belonging to 119 genera and 63 families. Among this, 67 woody species with 903 individuals and 52 genera were documented. The highest relative frequencies were recorded by *Anogeissus leiocarpa* (83.37%), *Pouteria alnifolia* var. *alnifolia* (73.37%), *Cola gigantea* (50%), *Diospyros mespiliformis* (50%) and *Dialium guineense* (40%). The lianas species are dominated by *Rourea coccinea*, *Dioscorea dumetorum*, *Cissus populnea*, *Dioscorea burkilliana* whereas the dominated herbaceous of the undergrowth layer were *Anchomanes difformis*, *Chromolaena odorata*, *Olyra latifolia* and *Oplismenus hirtellus*. The study revealed that trees bushfire and breakage are the main threats on species diversity. The most dominated plant species was found to be *A. leiocarpa*. The study suggests conservation strategies to protect woody species against anthropogenic pressures (for example, protection from or reducing the frequency and/or intensity of disturbance, especially woodcutting and bushfires).

Most diverse groups of species play a significant role in the conservation and sustainable use of biodiversity. Studies have revealed that the species diversity pattern varies with the population of different taxa. Hence, the data of just a few selected species will not be enough if we want to get a complete knowledge about the biodiversity of a region [11, 12].

2.2. Threats to Biodiversity

Species extinction is one of the major outcomes of the threats to biological diversity. Extinction of a species can lead to the loss of a factor that was responsible for keeping the ecosystem balanced, thereby misbalancing it to some extent. Loss of species not only affects the ecosystem globally but also has a huge impact locally. Some of the factors which threaten the species extinction are mentioned as follows:

- Pollution
- Habitat Loss
- Invasion of non-native species
- Climate change
- Over hunting

Amongst these above mentioned factors, the first two are the main factors responsible for loss in floral diversity. One of the main reasons behind the increasing pollution in the environment is the advent of industrialisation in the modern civilization. Mining industry is an integral part of the industrialisation and modernisation. Different stages of mining have different effects on the environment. Mining activities render the area barren thereby creating loss of habitat for the plants previously present there and also, after mining the land gets filled with harmful chemicals and industrial wastes which make the environment too polluted for any kind of vegetative propagation [13, 14].

2.3. Conservation of Biodiversity

The gradual and steady decrease of the forest lands in tropical countries has grabbed the attention of many researchers and they have been working to make the tropical forests more productive while taking care of maintaining the biodiversity too. The first priority for the maintenance of biodiversity is to decrease logging and to increase area for forests and restricting the forests for deforestation activities. Halting the building of roads and stopping commercial logging practices are the main mechanisms that need to be followed for the conservation of forests [15, 16].

But since, mining cannot be abolished because that will bring a huge blow to the economy, special measures should be taken in order to conserve the biodiversity. The area of land under mining activities should be carefully monitored for the kind of vegetation and environmental conditions that the area experiences. Accordingly, the area should be replanted after the mining activities are over. Also, a broader area around the core mining area, which is called the buffer area, should be monitored too. The buffer area is generally the area of about 10km radius around the core area. For every loss in the core area, there should be equal or more plantations in the buffer area for the compensation of the loss in biodiversity. Only when all these requirements are met with, should there be a clearance for the mining activities in ore-rich areas. If these conditions are properly met with, conservation of biodiversity would be taken care of [17].

2.4. Floral Diversity Calculation

In order to find out the species density we need to find out the number of individuals in a unit area. This unit area is kept fixed for the entire study area and it is essential for determining quantitative analysis vegetation. This fixed sample area is called “quadrat” and it is generally of a given shape and area. There can be three types of species distribution – random, regular and aggregate.

1-ha plot was used to determine the plant species diversity of the coastal forest within the Pasir Tengkorak Forest Reserve in Malaysia. The plants with diameter above 1.0 cm at breast height, or 4.5 feet above ground level, were considered. Species diversity was expressed by combining species richness and species evenness. The jackknife estimate and species-area curve were applied to find out the species richness. The three main diversity indices used for the estimation were Simpson's index of diversity, Shannon-Weiner function and Brillouin index. Simpson's measure of evenness, Camargo's index of evenness and Smith and Wilson's index of evenness were also used to estimate species evenness. Among 3414 individual trees the recorded data was of 120 species, 81 genera and 31 families. The highest relative abundance of species were found for *Swintonia sp1* (0.12), *Garcinia eugnifolia* (0.09) and *Syzygium sp1* (0.05). Species diversity was high with Simpson's index of diversity with a value of 0.96, while Shannon-Weiner index was 5.42 and Brillouin's Index was 5.14. However, Simpson's measure of evenness, Camargo's index of evenness and Smith and Wilson's index of evenness were 0.264, 0.378, and 0.419, respectively [18].

2.5. Ethnobotanical studies

The use of plants in the prevention and cure of various diseases of humans and animals is highly prevalent. With the advent of civilization, many plant based therapeutic techniques have been developed. Even to this day traditional phyto-medical systems provide to the basic health care to more than 75% of the world's population. Officially it has been recognized that 2500 plant species have medicinal value while over 6000 plants are thought to be explored in folk medicine. Proper utilization of raw materials found in the country can be done if there has been a survey of its natural resources and an inventory is prepared. It is important that we should have complete knowledge regarding the occurrence, frequency, distribution and phenology of all the plants for their exact utilization. The forests and barren regions of Rajasthan are potentially important both from the economic and botanical points of view [8, 19].

Although plant derived traditional medical systems are one of the major elements in human civilization, yet it has been pointed out by many that not much is known about the extensive uses of the medicinal herbs. It is of radical importance to know more about the relationship between the plants and the human beings, in every field, not only medicinal aspect [20].

Ethnobotany, as a research field of science, has been widely used for providing an inventory of useful plants from local sources in Asian countries and for the documentation of indigenous knowledge on the use of plants [21]. Plants that are utilized for conventional natural medication as a part of diverse nations are a critical part of these studies. Be that as it may, in a few nations recently, ethnobotanical studies have been utilized for the disclosure of new medications and new medication improvement. All in all, experiences gathered from ethnobotanical methodologies of conventional medicinal studies in China and Himalayan nations have helped drug creation and improvement. At the same time, in many cases, over-cultivation and degradation of medicinal plants and loss of traditional medical ideas in local communities are common problems in these resource areas. Issues of indigenous knowledge, IPR and uncontrolled cross country trade in medicinal plants occur frequently.

2.6. Mitigation Measures

An area experiencing mining activities faces a lot of environmental changes such as loss of vegetation, soil erosion, air pollution etc. These factors have a huge impact on the climate of that area as well as the biodiversity. In order to minimise the incurred loss, steps should be taken to help the climate of that area to retain its sanctity, as much as possible [22]. But it is difficult to do so as creating new infrastructure to cope up with a range of changing climate as large as this is very expensive. Also, it is not possible to know for sure, what exact changes are going to appear and the required information about the changes cannot be derived so easily. In order to prepare for such a situation the future infrastructure should be made robust so that it can acclimatize to the changes as they come. Some of the methods that can be employed for addressing the aforementioned problem are (i) selecting ‘‘no-regret’’ strategies that yield benefits even in absence of climate change; (ii) favouring reversible and flexible options; (iii) buying ‘‘safety margins’’ in new investments; (iv) promoting soft adaptation strategies, including long-term prospective; and (v) reducing decision time horizons.

Defiled soils and waters represent a noteworthy ecological and human wellbeing issue, which may be halfway settled by the rising phytoremediation innovation. This cost-effective plant-based way to deal with remediation exploits the wonderful capacity of plants to think components and mixes from the earth and to metabolize different atoms in their tissues. Harmful overwhelming metals and natural contaminations are the significant focuses for phytoremediation. Lately, information of the physiological and atomic instruments of phytoremediation started to rise together with natural and designing procedures intended to enhance and enhance phytoremediation. Moreover, a few field trials affirmed the practicality of utilizing plants for ecological cleanup [23, 24].

Chapter 3

Materials and Methods

The study was carried out in the Sarkunda Reserve Forest of Keonjhar District in Odisha. The area is rich in iron ores. Due to the high availability of iron ores, the area houses some of the prominent iron mines of the country.

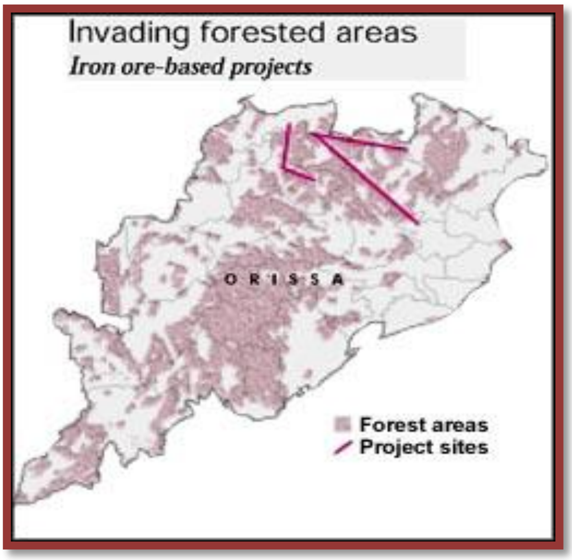


Fig 1. Iron ore projects in Odisha

Field trip was conducted in and data was collected from the Sarkunda Reserve Forest. Plant samples were identified and counted with the help of Quadrat method. Multiple quadrat data were then compiled and extrapolated in order to evaluate the diversity of the floral cover of the region.

3.1. Study Area

The present study area comprised of the core region and the buffer region of the iron mining industry based in Sarkunda Reserve Forest. The core region is the region which has been allotted for the proposed iron mining industry, whereas, the buffer region comprises of the area of about 10km radius around the core region. The study area is mainly dense forest with floral cover and some small villages with tribal people dwelling in them.

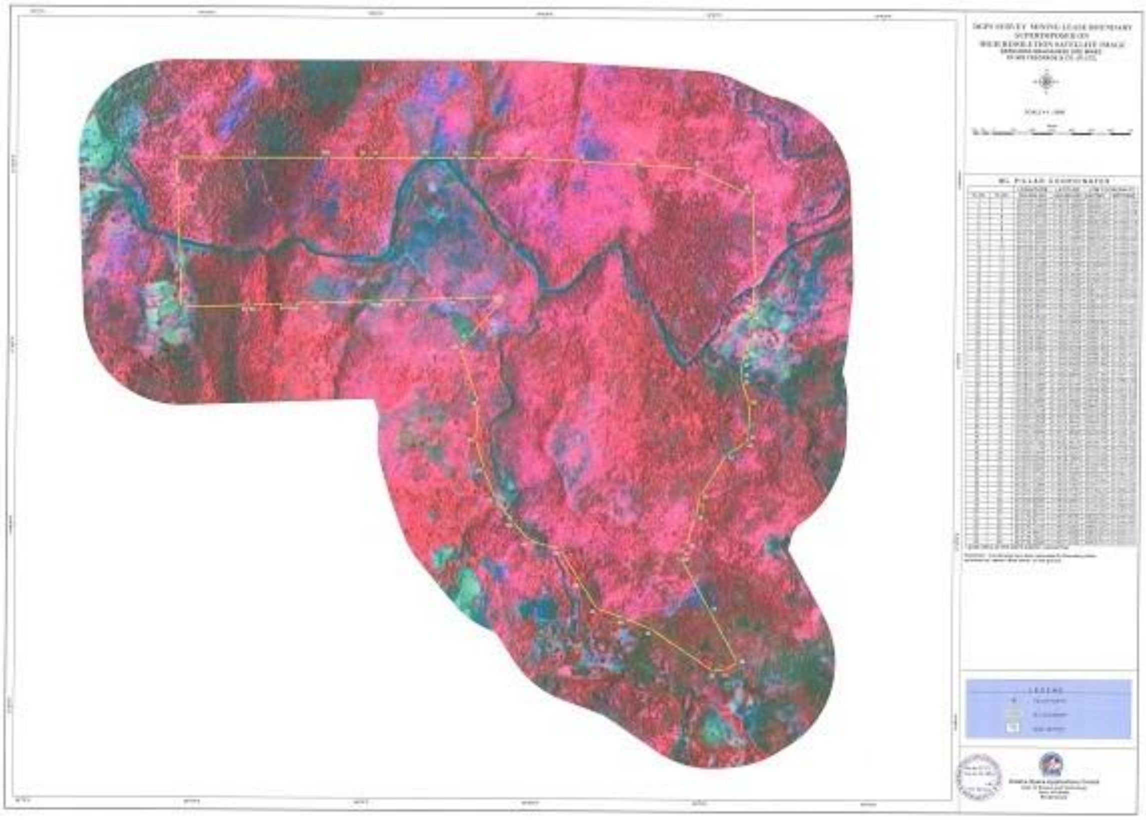


Fig 2. Map of the Study Area

3.2. Sample Collection and Identification

The study area was examined in a daily basis during the field surveys. Field survey was conducted in every season throughout a year. Random points were chosen in the study area, the latitude-longitude coordinates were recorded with the help of a GPS. In those selected points the floral cover of a 10mX10m area was created with the help of ropes and poles. This $100m^2$ area was then surveyed by getting a thorough count of the number of plants in it. Any unknown plant species was either photographed or collected in order to get it identified later on. Rest were identified, enumerated and documented.

The most popular method used for the counting of the plants was the Quadrat method. The Quadrat method is one of the oldest as well as the most effective method of getting a comprehensive idea about the floral cover in a place. The Quadrat method is defined as the method in which a definite circumscribed area is used to count the number of individuals of a plant species present in it. This definitive circumscribed area can be achieved with the help of anything that can be moulded into a fixed area viz. a wooden frame or ropes and poles etc. This frame is then placed on the area, the floral cover of which has to be studied. The individual species of plants that come within the enclosed area were counted and noted down [25].

We created our quadrate with the help of rope and poles, creating a boundary of $100m^2$ in our designated spot, followed by counting and enumerating the plant species found over there.

The plant species were identified with the help of noted taxonomist. The reference from flora's books [26] and published article were also used to identify plant species. Rare and vulnerable plant species were noted down so that their presence can be reported.

Also, the local tribal people were questioned regarding their daily uses of plants for their medicinal importance or nutritional source and economic values. This helped us in creating a database of plants with their ethnobotanical uses.

3.3. Species Diversity Calculation

In each quadrate, data was gathered by manually counting the different species of plants – trees, shrubs, herbs, climbers, creepers etc. The data were collected, classified and analysed to calculate diversity indices and evenness quotients.

Species diversity is a defined as the measure of the diversity within an ecological population that includes both species richness (the number of species in a community) and the evenness of species' abundances [27].

Species richness is one of the most important elements in biodiversity, because the number of species existing at a site is a quantitative measure of biodiversity and it allows comparison with other sites.

3.3.A. Shannon-Wiener Index: One of the most popular diversity indices used to measure species diversity [28]. It is given by the following formula:-

$H = -\Sigma\ (p_i)\ (\ln p_i)$ $\qquad 0 < H < 5$

Where, H – index of species diversity

S – No. of species

p_i – proportion of total sample belonging to the i^{th} species (n_i/N)

ln – natural log

n_i - No. of individuals of each species

N – Total number of species

3.3.B. Simpson's Index: Another popular method of calculating the species diversity. This measure defines that the probability of two entities taken at random from a dataset represent the same species [29]. It can be defined by the following formula:-

$D = \Sigma p_i^2 = \Sigma n(n-1)/N(N-1)$

Where, D – Simpson's Index

p_i – proportion of species i in the community

3.3.C. Simpson's Index of diversity: this measure is given by (1 – D) and the value ranges from 0 to 1, 0 being the lowest diversity and 1 being the highest.

3.3.D. Simpson's Measure of Evenness: Another method of species richness is called species evenness. In this case, Simpson's Measure of Evenness has been calculated in order to find out the evenness with the help of the following formula:

$E = (1/D)/s$

Where, E – Simpson's Evenness

D – Simpson's Index

s – Number of species in the sample

3.3.E. Effective Number of Species: Diversity indices as the Shannon-Wiener Index and the Simpson's Index, mentioned above, use their own different formulae to determine the species diversity. Also, these indices are not the exact measures of the number of individuals of a species in a community. In order to compare the species numbers, need was felt to bring the indices in a common platform with the help of which one can bring down the count of the individuals in a layman's level [29]. Effective number of species (ENS) helps bringing the Shannon-Wiener Index to a similar level. It can be calculated as:-

$ENS = \exp(H)$

Where, H – Shannon Wiener Index

This is elaborated as, a community with a Shannon-Wiener Index H, has an equivalent diversity as a community with ENS equally common species.

3.4. Questionnaire Survey

In order to create a database of the ethnobotanical uses of the plants that were found in the study area, we prepared a questionnaire with some specific questions regarding the uses of the plants. The tribal villages present in the study area were covered. The tribal people and the tribal medicine men were questioned about the plants and their cultivation techniques, if any. This was used to gather idea about the types of plantation the area supported, according to the weather conditions.

3.5. Mitigation Measures

The data about the weather conditions of the area and the plantation history of the area helped in finding out the mitigation measures that should be employed to prevent biodiversity loss, as much as possible.

Chapter 4

Results and Discussion

4.1. Sampling Area

The sampling area was comprised of the villages and the forest areas of the Sarkunda Reserve Forest. The villages that were part of the study are are Ronda, Bhutula and Domalu, of Kendujhar (Keonjhar) district of Odisha. The latitude-longitude coordinates of the villages and the reserve forest were recorded with the help of GPS.

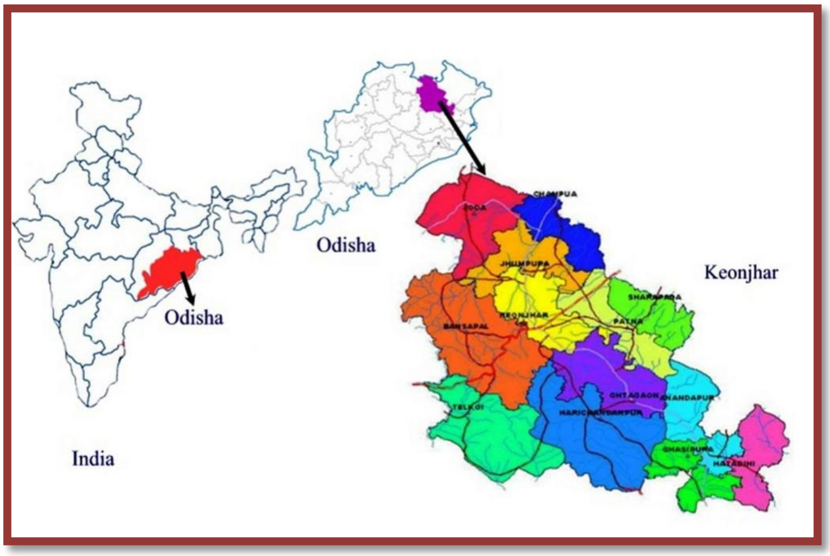


Fig 3. Keonjhar district of Odisha, India

4.2. Locations of Quadrats

The GPS co-ordinates of the qudrats that were taken in the study area, have been documented and plotted in the map.

Table 1. Location Co-ordinates of Study Area

Sl.no.	Village name	GPS co-ordinates	WGS84	Area (in acres)
1.	Bhutula	21^{o}49’12.86” N 85^{o}09’08.38” E	21.820238888888888, 85.15232777777778	505.21
2.	Ronda	21^{o}49’22.06” N 85^{o}08’11.09” E	21.822794444444444, 85.1364138888889	145.39
3.	Domalu	21^{o}49’04.08” N 85^{o}09’08.38” E	21.8178, 85.15232777777778	5.50
4.	Reserve Forest	21^{o}49’23.06” N 85^{o}07’24.04” E	21.823072222222223, 85.12334444444444	316.4

Fig 4. GPS points of the quadrants in the study area

Fig 5(a) and 5(b): Taking Quadrat data with the help of ropes and poles

Table 2. Documentation of data in the Quadrats

Quadrat Number	**Coordinates in decimal**	**Enumeration**					
		Trees	**Shrubs**	**Herbs**	**Climbers**	**Creepers or Prostrates**	**Dominant species number and name**
1	21.8202388888888, 85.1523277777777	228	58	36	36	--	102 *Wrightia tinctoria*
2	21.8227944444444, 85.1364138888889	116	104	28	18	--	62 *Atlantia monophylla*
3	21.8178, 85.1523277777777	66	130	84	10	12	70 *Flemingia grahamiana*
4	21.8230722222222, 85.1233444444444	24	117	74	12	138	122 *Evolvulus nummularius*

5	21.8230008, 85.1433237	38	234	52	--	534	530 *Evolvulus nummularius*
6	21.81879999, 85.1455349	18	86	354	2	66	332 *Cassia oxydentalis*
7	21.8129999, 85.1276889	31	239	347	15	97	306 *Cassia oxydentalis*
8	21.82377, 85.12666599	291	161	126	31	12	278 *Wrightia tinctoria*
9	21.8230899, 85.12345	53	341	297	19	106	311 *Flemingia grahamiana*
10	21.8229, 85.151112399	49	103	262	136	164	228 *Cassia oxydentalis*
11	21.82111, 85.12111233	128	37	35	6	2	98 *Wrightia tinctoria*
12	21.821000067, 85.13640012	213	141	108	39	12	102 *Shorea robusta*
13	21.8199999, 85.1364111	267	105	119	10	10	121 *Shorea robusta*
14	21.815111009, 85.1277	121	225	125	115	19	101 *Celastrus paniculata*
15	21.8211000044, 85.129999	212	201	140	141	16	112 *Celastrus*

							paniculata
16	21.8221119, 85.13	287	219	138	105	20	130 *Flemingia grahamiana*
17	21.8227778, 85.123333	265	266	151	105	20	111 *Wrightia tinctoria*
18	21.8233569, 85.129999	280	277	169	101	18	68 *Celastrus paniculata*

A total of 10478 individual plants representing 158 species and 62 families were recorded within the study area. The above mentioned species were found in abundance.

4.3. List of Plants

The plants observed in the study area have been enumerated and documented in the following table with their local names and family names. The plants were observed and their growth habits have also been recorded. It has been mentioned whether the plants are rare, vulnerable or common. Finally, their ethnobotanical uses have been documented that have been gathered through questionnaire survey of local people as well as through various literature surveys [30-32].

Fig 6. Identification of flora by the taxonomist

Fig 7. Questionnaire survey

Table 3. List of Plant Species identified and their ethnobotanical uses

Sl. No.	Scientific name	Local Name	Family Name	Habit	Status	Significant Characteristics
1	*Abroma anguste*	Ultakamal	Sterculiaceae	Shrub	Common	Wild ornamental
2	*Abrus precatorius*	Kaincha	Fabaceae	Climber	Common	Medicinal, ornamental, socio-cultural
3	*Abutilon indicum*	Pedhipedhika	Malvaceae	Shrub	Rare	Medicinal, Edible
4	*Acacia auriculiformis*		Mimosaceae	Tree	Common	Economical
5	*Aegle marmelos*	Bel	Rutaceae	Tree	Common	Medicinal, economical, edible
6	*Ageratum conyzoides*	Pakkasundar	Asteraceae	Shrub	Common	Medicinal
7	*Alangium salvifolium*	Ankoli	Alangiaceae	Shrub	Common	Wild weed
8	*Alocasia montana*		Arecaceae			
9	*Alstonia scholaris*	Indian Devil Tree	Apocynaceae	Tree	Common	Economical

10	*Anacardium occidentalis*	Hijlibadam	Anacardaceae	Tree	Common	Edible, Economical
11	*Andrographis paniculata*	Chirota	Acanthaceae	Herb	Common	Medicinal, economical
12	*Annona squamosa*	Sitaphal	Annoneaceae	Tree	Common	Edible
13	*Arisaema erubescens*		Araceae			
14	*Asparagus racemosus*	Satabhari	Asparagaceae	Climber	Vulnerable	Medicinal, Economical
15	*Atalantia monophylla*	Wild Lime	Rutaceae	Shrub	Common	Medicinal, Edible
16	*Atlosia scarabacoides*	Banakultha	Fabaceae	Climber	Common	Edible
17	*Azadirachta indica*	Neem	Meliaceae	Tree	Common	Edible, Medicinal, economical
18	*Baliospermum montanum*	Danti	Euphorbiaceae	Shrub	Common	Medicinal
19	*Bambusa arundinaceae*	Kanta Bans	Poaceae	Grass	Common	Economical
20	*Bauhinia vahlii*	Siyali patra	Fabaceae	Climber	Common	Medicinal, economical

21	*Benkara malbarica*	Kontakoli	Rubiaceae	Tree	Common	Medicinal
22	*Buchanania lanzan*	Chironji	Anacardiaceae	Tree	Common	Edible
23	*Cajanus cajanifolia*	Pigeon Pea	Fabaceae	Shrub	Common	Edible
24	*Careya arborea*	Khumbhi	Lacythidaceae	Tree	Common	Edible
25	*Caryota urens*	Fishtail palm	Araceae	Tree	Common	Edible
26	*Cassia fistula*	Sonari	Caesalpiniaceae	Tree	Common	Medicinal, Economical
27	*Cassia occidentalis*	Kaashunda	Caesalpiniaceae	Shrub	Common	Medicinal
28	*Cassia saima*	Sakunda	Caesalpiniaceae	Tree	Common	Medicinal
29	*Cassia tora*	Chhota chakunda	Fabaceae	Shrub	Common	Medicinal
30	*Celastrus paniculatus*	Kujri	Celastraceae	Climber	Vulnerable	Medicinal, Socio-cultural
31	*Centella asiatica*	Thalkudi	Apiaceae	Herb	Common	Medicinal, economical
32	*Cissampelos pareira*	Kumutia	Verbenaceae	Shrub	Common	Medicinal
33	*Cleistanthus collinus*	Pitusing	Menispermaceae	Vine	Common	Medicinal
34	*Cleome monophylla*	Oduva	Euphorbiaceae	Tree	Rare	Poisonous

35	*Clerodendrum inerme*	Ranga Sorisha	Capparaceae	Shrub	Common	Medicinal
36	*Clerodendrum viscosum*	Vanajai	Verbenaceae	Shrub	Common	Medicinal
37	*Cocculus hirustus*	Karada	Menispermaceae	Climber	Common	Medicinal
38	*Colocasia esculanta*	Saru	Araceae	Climber	Common	Edible
39	*Commelina ensifolia*	----	Commelinaceae	Prostrate	Common	Edible
40	*Costos speciosus*	Kankanka	Costeaceae	Shrub	Common	Medicinal, edible
41	*Curculigo orchioides*	Kali musli	Hypoxidaceae	Herb	Common	Medicinal
42	*Curcuma amada*	Amada	Zingiberaceae	Herb	Common	Edible
43	*Curcuma aromatica*	Haldi	Zingiberaceae	Herb	Common	Edible
44	*Cuscuta reflexa*	Konalimuli	Convolvulaceae	Weed	Common	Weed
45	*Cycas ramphii*		Cycadaceae	Tree	Common	Ornamental
46	*Cyperus rotumdus*	Mutha	Cyperaceae	Herb	Common	Edible
47	*Dalbergia sissoo*	Sissoo	Fabaceae	Tree	Common	Economical

48	*Desmodium gangeticum*	Anshumati	Fabaceae	Shrub	Common	Medicinal
49	*Desmodium pulchellum*	Krishnaparni	Fabaceae	Shrub	Common	Medicinal
50	*Dillenia indica*	Aou	Dilleniaceae	Tree	Common	Edible
51	*Dillenia pentagyla*	Ouu	Dilleniaceae	Tree	Common	Edible
52	*Dioscorea bulbifera*	Pita aalu	Dioscoreaceae	Climber	Common	Edible, Medicinal, Economical
53	*Dioscorea pentaphylla*	Panja sanga	Dioscoreaceae	Climber	Common	Edible
54	*Dioscorea puber*	Kukai sanga	Dioscoreaceae	Climber	Common	Edible
55	*Dioscorea wallichii*	Suta aalu	Dioscoreaceae	Climber	Common	Edible
56	*Dioscoria esculenta*	Konta aalu	Dioscoreaceae	Climber	Common	Edible
57	*Dioscoria hamiltonii*	Mera,tua sanga	Dioscoreaceae	Climber	Common	Edible, medicinal
58	*Dioscoria hispida*	Baya aalu	Dioscoreaceae	Climber	Common	Edible

59	*Diospyros melanoxylon*	Kendu	Ebenaceae	Tree	Common	Edible, economical
60	*Eclipta alba*	Bhingraj	Asteraceae	Prostrate	Common	Medicinal
61	*Eclipta prostrate*		Asteraceae			
62	*Elephantopus scaber*	Mayurachula	Asteraceae	Herb	Common	Edible, economical
63	*Emblica officinalis*	Amla	Euphorbiaceae	Tree	Common	Edible, Medicinal, economical
64	*Emilia sonchifolia*	Binj kudo	Asteraceae	Herb	Common	Medicinal
65	*Eucalyptus polybractea*	Eucalyptus	Myrtaceae	Tree	Common	Medicinal
66	*Eupatorium odoratum*		Asteraceae	Weed	Common	Weed
67	*Euphorbia hirta*	Chittakuttei	Euphorbiaceae	Prostrate	Common	Medicinal
68	*Evolvulus nummularius*	Musakarni	Convolvulaceae	Prostrate	Common	Medicinal
69	*Ficus parasitica*		Moraceae			
70	*Ficus semicordata*		Moraceae			

71	*Flemingia grahamiana*	----	Fabaceae	Shrub	Common	Medicinal
72	*Flemingia stricta*	Uskura	Fabaceae	Shrub	Common	Medicinal
73	*Gardenia gummifera*	Kikimali/ Dekamari	Rubiaceae	Tree	Rare	Medicinal
74	*Gardenia latifolia*	Papara	Rubiaceae	Tree	Common	Medicinal
75	*Glycosmis pentaphylla*	Kadudibadi	Runtaceae	Shrub	Common	Medicinal
76	*Guazuma ulmifolia*	Debodaru	Sterculiaceae	Tree	Common	Medicinal
77	*Hedyotis corymbosa*	Gharapoadia	Rubiaceae	Herb	Common	Medicinal
78	*Helicteres isora*	Baranga	Sterculaceae	Shrub	Common	Medicinal
79	*Hemidesmus indicus*	Duddhi	Asclepiadaceae	Climber	Common	Medicinal
80	*Holarrhena pubescens*	Kherwa	Apocynaceae	Tree	Common	Medicinal
81	*Holorrhena antidysentrica*	Pita koron	apocynaceae	Tree	Common	Medicinal
82	*Hyptis suaveolens*	Ganga Tulsi	Lamiaceae	Herb	Common	Medicinal

83	*Ichnocarpus frutescens*	Shyamlata	Apocynaceae	Climber	Common	Medicinal
84	*Indigofera cassioides*	Girli	Fabaceae	Shrub	Common	Edible
85	*Jatropa curcas*	Danti	Euphorbiaceae	Shrub	Common	Economical
86	*Jatropha gossypifolia*	Dumajada	Euphorbiaceae	Shrub	Common	Medicinal
87	*Lannea coromandelica*	Mahi	Anacardiaceae	Tree	Common	Edible
88	*Lantana camara*	Jaikoli	Verbenaceae	Shrub	Common	Medicinal
89	*Lasia spinosa*	Kohila	*Araceae*	Herb	Common	Edible
90	*Lawsonia inermis*	Manjuati	Lythraceae	Shrub	Common	Medicinal
91	*Leucas aspera*	Chero	Lamiaceae	Weed	Common	Weed
92	*Lygodium flexuosum*	Indrajaal	Ligodiaceae	Herb	Common	Wild weed
93	*Madhuca longifolia*	Mahulo	Sapotaceae	Tree	Common	Economical
94	*Mallatus phillippensis*	Sindoori	Euphorbiaceae	Tree	Common	Medicinal
95	*Mangifera indica*	ambo	Anachardeaceae	Tree	Common	Edible

96	*Melastoma malabathricum*	Mahagomy	Meliaceae	Tree	Common	Economical
97	*Melia azadirachta*	Nageswar	Guttiferea	Tree	Common	Medicinal
98	*Mesua ferrea*	Shiah kanta	Mimoceae	Tree	Common	Wild weed
99	*Mimosa himalayana*	Lajakulilata	Mimosaceae	Herb	Common	Ornamental
100	*Mimosa pudica*	Munde	Rubiaceae	Tree	Common	Medicinal
101	*Mitragyna parvifolia*	Aalo	Rubeaceae	Tree	Common	Fruits for monkey
102	*Morinda tinctoria*	Somla	Moringaceae	Tree	Common	Edible, Medicinal
103	*Moringa oleifera*	Gongoi	Melastomataceae	Shrub	Common	Wild ornamental
104	*Mucuna preriena*	Baidanka	Fabaceae	Climber	Common	Medicinal, economical
105	*Murraya paniculata*	Kamini	Rutaceae	Shrub	Common	Edible
106	*Ocimum basilicum*	Black tulsi	Lamiaceae	Herb	Common	Medicinal, socio-cultural
107	*Ocimum gartisimum*	Karpuro tulsi	Lamiaceae	Herb	Common	Medicinal
108	*Oroxylum indicum*	Phampana	Bignoniaceae	Tree	Common	Medicinal

109	*Passiflora foetida*	Gandha Tamala	Passifloraceae	Vine	Common	Medicinal
110	*Pavetta nanceouata*		Rubiaceae			
111	*Phoenix sylvestris*	Khajuri	Araceae	Palm	Common	Edible
112	*Phyllanthus amarus*	Tamalaki	Phyllanthaceae	Weed	Common	Weed
113	*Phyllanthus niruri*	Bhui Amla	Phyllanthaceae	Herb	Common	Medicinal
114	*Phyllanthus reticulates*	Amla	Euphorbiaceae	Tree	Common	Edible, Medicinal
115	*Phylranthus officinalis*	Jejhang	Euphorbiaceae	Shrub	Common	Edible
116	*Piper longum*	Pippali	Piperaceae	Climber	Common	Edible, Medicinal
117	*Plumeria alba*		Apocynaceae			
118	*Premna latifolia*		Verbenaceae			
119	*Pterocarpus marsupium*	Bijasal	Fabaceae	Tree	Common	Medicinal
120	*Pterospermum xylocarpum*	Muchkund	Sterculaceae	Tree	Common	Economical
121	*Pterospermum xylocarpus*	Giringa	Sterculiaceae	Tree	Common	Medicinal

122	*Pueraria tuberose*	Bhuin pokharu	Fabaceae	Climber	Rare	Medicinal, edible, economical
123	*Rauvolfia serpentine*	Patalgaruda	Apocynaceae	Shrub	Rare	Medicinal
124	*Relipta prostrate*	Bhrungaraj	Asteraceae	Prostrate	Common	Medicinal
125	*Rubas tamilnadia*	----	Rubiaceae	Shrub	Common	Weed
126	*Rubia cordifolia*	Atha koli	Rubeaceae	Climber	Common	Medicinal
127	*Rungia pectinata*	---	Rubeaceae	Herb	Common	Medicinal, edible
128	*Samanea saman*	Gulabi siris	Mimosaceae	Tree	Common	Economical
129	*Scindapsus officinalis*	Partogaja/gajapeepli	Araceae	Climber	Rare	Medicinal
130	*Semecarpus anacardium*	Soso	Anacardiaceae	Tree	Common	Medicinal
131	*Semicarpus anacardium*	Bhalia	Anacardiaceae	Tree	Common	Edible, economical
132	*Shorea robusta*	Sal	Dipterocarpaceae	Tree	Common	Economical
133	*Smilax zeylanica*	Ramadantuni	Smilaceae	Climber	Common	Medicinal
134	*Solanum nigrum*	Bhejri	Solanaceae	Herb	Common	Edible

135	*Spathodea campanulata*	----	Bignoniaceae	Tree	Common	Medicinal
136	*Stone lamiates*	----	Lamiaceae	Shrub	Common	Grows on stone
137	*Synedrella nodiflora*	Badi Pokasunga	Asteraceae	Shrub	Common	Medicinal
138	*Syzgium cumini*	Jamun	Myrtaceae	Tree	Common	Edible
139	*Tephrosia purpurea*	Paharagacha	Fabaceae	Tree	Common	Medicinal
140	*Terminalia arjuna*	Arjuna	Combretaceae	Tree	Common	Ornamental, Medicinal
141	*Terminalia bellirica*	Bahada	Combretaceae	Tree	Common	Medicinal
142	*Terminalia catappa*	Desibadam	Combretaceae	Tree	Common	Medicinal, edible, economical
143	*Terminalia chebula*	Harda	Combretaceae	Tree	Common	Medicinal
144	*Terminalia roxburghii*	Atundi	Combretaceae	Tree	Common	Medicinal
145	*Terminalia tomentosa*	Aasan	Combretaceae	Tree	Common	Economical
146	*Toddalia asiatica*	Tundapoda	Rutaceae	Shrub	Common	Edible

147	*Triumfetta neglecta*	Nichardia	Tiliaceae	Shrub	Common	Medicinal
148	*Triumfetta rhomboidea*	Bidua	Tiliaceae	Shrub	Common	Economical
149	*Tylophora indica*	Mendi	Asclepiadaceae	Shrub	Common	Medicinal
150	*Urena lobata*	Rakta Pheni	Malvaceae	Shrub	Common	Economical
151	*Vernonia cinerea*	Pokasunga	Asteraceae	Shrub	Common	Medicinal
152	*Vitex altissima*	----	Verbenaceae	Climber	Common	Edible for birds
153	*Vitex negundo*	Baigunia Sindura	Verbenaceae	Climber	Common	Medicinal
154	*Woodfordia fruitcosa*	Dhartiki	Lytharaceae	Shrub	Common	Medicinal
155	*Wrightia tinctoria*	Koruan	Apocynaceae	Tree	Common	Medicinal
156	*Zizyphus jujube*	Ber	Rhamnaceae	Tree	Common	Edible
157	*Zizyphus oenoplia*	Kanteikoli	Rhamnaceae	Shrub	Common	Medicinal
158	*Zizyphus rugosa*	Tin koli	Rhamnaceae	Tree	Common	Edible

Table 4. Enumeration of Dominant Flora and Relative density of the species

Dominant Plant Species	Number	Relative density
Atlantia monophylla	62	0.59
Shorea robusta	223	2.13
Celastrus paniculata	281	2.68
Flemingia grahamiana	511	4.88
Wrightia tinctoria	589	5.62
Evolvulus nummularius	652	6.23
Cassia oxydentalis	866	8.26
Others	7294	69.61
Total	10478	100

4.4. Floral Diversity Chart

Comparison of the presence of the number of individuals of all the growth habits was carried out to find out the abundance of species.

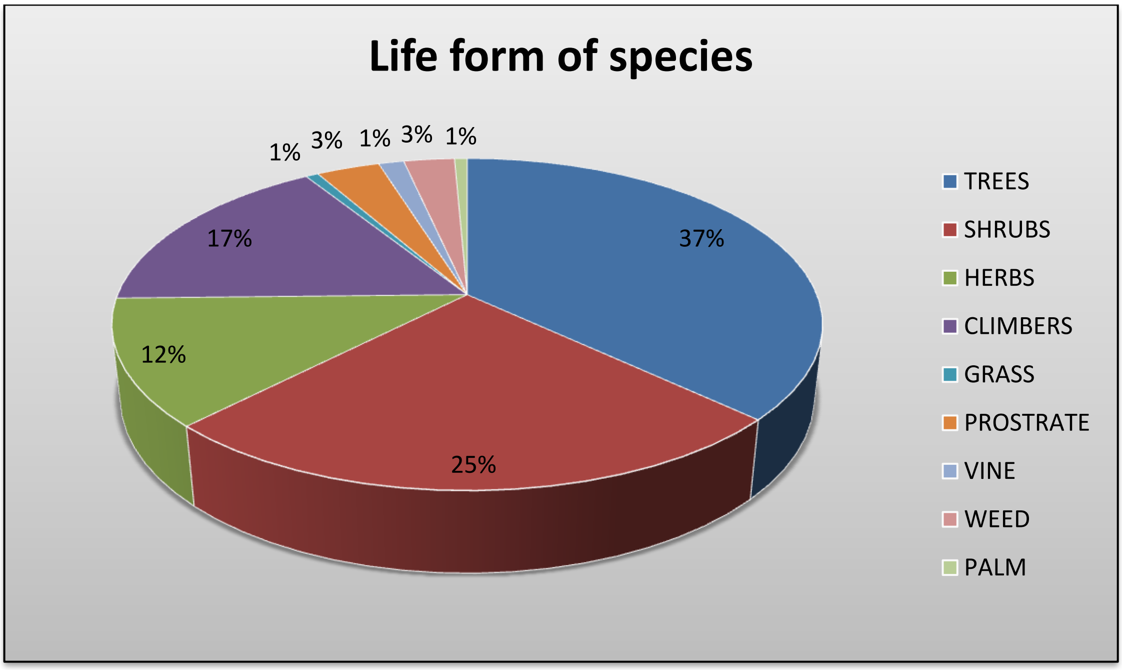


Fig 8. Pie chart representing the percentage cover of plants from different life forms

4.5. Species Diversity Calculation

Shannon-Wiener Index: The index used to determine the frequency of presence of plants of different growth habits, taken from all the quadrates from the study area.

$H = -\Sigma(p_i)(\ln p_i)$, in which the value ranges from 0 to 5, 5 being the measure for the highest diversity.

Result: H = - [(0.0562) (- 2.878) + (0.0059) (- 5.129) + (0.0487) (- 3.020) + (0.0212) (- 3.849) + (0.0622) (- 2.777) + (0.0826) (- 2.493)]

The Shannon-Wiener Index for the dominant plant species found in the study area was found to be H= 0.6669.

Effective Number of Species (ENS) was calculated from the H value.

ENS = e^0.6669 = 1.948 ≈ 2.

This is elaborated as, a community with a Shannon-Wiener Index of 0.6669, has an equivalent diversity as a community with 2 equally common species.

Simpson’s Index: This index measures the possibility that two individuals, randomly selected in a community will belong to the same species or same category of a parameter. Simpson’s index of diversity is measured for data acquired from the study area from the 18 quadrats. The value of Simpson’s Index ranges from 0 to 1, the value being closer to 1, indicates lower diversity than the value closer to 0.

Conversely, Simpson’s Index of Diversity is given by subtracting Simpson’s index from 1, in that case the higher the value, the higher is the diversity.

Table 5. Diversity Indices

Simpson's Index (D)	0.0174
Simpson's Index of Diversity (1-D)	0.9825

Simpson's Measure of Evenness: This value helps in understanding the species richness of the area.

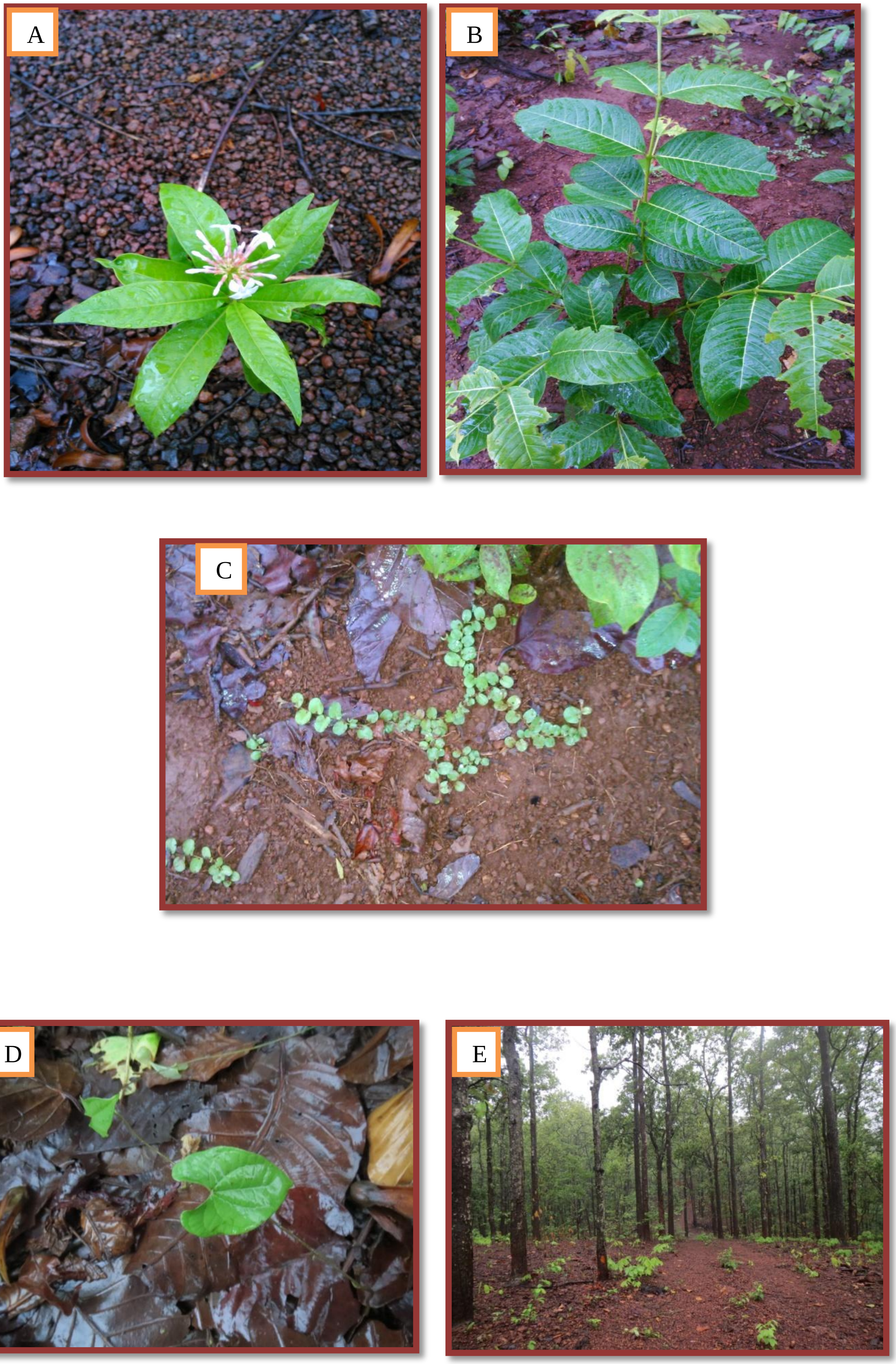
E = (1/D)/s = (1/0.0174)/158 = 0.363

4.6. Key Findings

Some of the plant species observed in the study area were listed as RET (Rare, Endangered and Threatened) [33]species. The names are as follows:-

- *Scindapsus officinalis*
- *Pueraria tuberosa*
- *Gardenia gummifera*
- *Rauolfia seperntina*
- *Asparagus racemosus*
- *Ficus semicordata*
- *Mucuna gigantae*
- *Abutilon indicum*

Fig 9. Some of the plants observed and identified



A. *Rauwolfia serpentine*

B. *Wrightia tinctoria*

C. *Evolvulus nummularius*

D. *Dioscorea alata*

E. *Shorea robusta*

F. *Bauhinia vahlii*

G. *Mucuna gigantea*

H. *Mimosa pudica*

I. *Annona reticulata*

4.7. Mitigation Measures

In order to save the loss of floral biodiversity, certain measures are to be taken. These are the mitigation measures that would help to sustain the biodiversity loss incurred due to the mining activities.

- The topsoil is the most hampered constituent of the environment, post mining activities. The most common method that can be used to revive the soil conditions is “revegetation”. To prepare the topsoil for revegetation, proper fertilizers should be used and soil should be inoculated with N_2- fixing bacteria.
- The buffer zone, ie. the area of about 10km diameter around the core zone of the mining region, should be the site for practising terrace planting, run-off channels, stabilization ponds and mulches.
- Organic wastes can also be used for soil amendments. Plant residues can be used as insulation of soil from extreme temperature fluctuations. Inert materials in the soil can act as insulation against migration of toxic materials to topsoil.
- Another effective method can be “Phytoremediation”. The method is defined as the use of green plants for the removal of the contaminants from the soil, rendering the soil harmless. There are two main types of Phytoremediation:-
    - Phytostabilisation – The main idea is to choose plants that are generally metal-tolerant and grows well and fast, in arid soil. These metal-tolerant plants along with zeolites immobilize soil metals. Eg.: - Indian Mustard, *Zea mays*, *Pisum sativum* etc. are known to have the ability to stabilize metal contamination in soil.
    - Phytoextraction – The idea behind this method is using plants that extracts and translocates heavy metals with the help of their roots to the above soil. These types of plants are called “Hyperaccumulator” plants. The plants of the following families are known to be effective hyperaccumulators:
        - Apiaceae
        - Asteraceae
        - Brassicaceae
        - Fabaceae
        - Lamiaceae
        - Liliaceae
        - Poaceae
        - Rosaceae

- Creating insurance for crops, i.e. for the loss of land used by the local tribal farmers there should be a scheme with the government to help them by providing them with the crops [34].
- In-vitro conservation techniques should be used to conserve the RET listed plants found in the study area, for that genetic stability of the plants and their storage duration should be checked.
- Seed banks should be maintained for the plants, so that loss in the plants during mining activities can be compensated as soon as possible.

4.8. Discussions

The Shannon Wiener Index for the floral population was found to be 0.6669. It was converted to Effective number of species which was obtained roughly as 2. This meant that a community with the Shannon Wiener Index 0.6669 has a diversity equivalent to a community with 2 equally common species.

The Simpson's Index of Diversity was calculated and it was found out that the value was 0.9825. When the value of Simpson's Index of Diversity is closer to 1, it denotes high species diversity. On the other hand, the Simpson's measure of evenness was found out to be 0.363 which is much below the value 1. Hence, it can be concluded that the species are not evenly distributed throughout the community.

In order to check the loss of soil and biodiversity, some mitigation measures have been suggested. Keeping those in mind, some plants are suggested for the same [35-37].

- *Brassica juncea*
- *Arabidopsis halleri*

- *Eichornia crassipes*
- *Azolla pinnata*
- *Zea mays*
- *Pisum sativum*
- *Azadirachta indica*
- *Dalbergia sissoo*

These plants have the capacity to extract heavy metals from the soil and make the soil less contaminated. These plants are termed as hyperaccumulator. Either they work on their own or they extract metals from the soil with the help of zeolites.

Chapter 5

Conclusion

Field survey for an entire year in the study area revealed that the highest species diversity was obtained during the monsoon season. The least species diversity was obtained during the spring season, because, after the maximum number of plants are dried and shed their leaves during the winter season. Hence, in order to find out the species diversity, the data collected during the monsoon season were of utmost importance.

Also, it was found out that the local tribal people who inhabit that area resort to deforestation for gathering timber. Along with that, in some areas, the forest was found to be burnt too, in order to get rid of wild rodents which were known to harm the crops a lot.

Identification of plant species led to the knowledge of the existence of some rare plant species, of which much abundant were *Raoulfia serpentine* and *Mucuna gigantean*. These plants have been recognized as rare plants in the state of Odisha. Their habitats can be harmed with the advent of mining activities. Hence, care should be taken to compensate the loss of these plants.

Certain measures should be taken before the starting of mining activities. Extensive plantations should be carried out in the buffer zone of the mining area. The buffer zone is the area of about radius of 10km around the core zone which is the main mining site. The study area has an abundance of *Shorea robusta* and *Wrightia tinctoria*. A few plants have been suggested for the soil reclamation and rehabilitation. Cultivation of those plants might help in the restoration of biodiversity and reduction of pollution.

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